DOCUMENT RESUME

ED 391 666 SE 057 614

AUTHOR	Raymond, Anne M.
TITLE	Mathematics Teacher Development: Lessons Learned from Two Collaborative Action Research Partnerships.
PUB DATE	Oct 95
NOTE	32p.; Paper presented at the Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (17th, Columbus, OH, October 21-24, 1995).
PUB TYPE	Speeches/Conference Papers (150) -- Reports - Research/Technical (143)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Action Research; College School Cooperation; *Educational Change; Junior High Schools; *Manipulative Materials; *Mathematics Teache-s; *Problem Solving; *Professional Development
IDENTIFIERS	*Teacher Change; Teacher Researcher Cooperation

ABSTRACT

Collaborative action research partnerships create rich opportunities for the professional development of teachers and classroom reform. This paper reports results from two action research projects. The first was a collaboration between the author and a seventh-grade mathematics teacher who wanted to change his mathematics teaching in an effort to more effectively address the National Council of Teachers of Mathematics' call to infuse problem solving into the mathematics classroom. The second collaborative project stemmed from an eighth-grade teacher's desire to investigate whether or not her efforts in teaching algebra through the use of a "Hands-On" manipulative program were worthwhile. Both projects were teacher-driven and yielded a number of interesting results. In this paper the two studies are described, the process of engaging in collaborative research is discussed, the similarities and differences between the roles of the university researcher in the two projects are discussed, and the role of action research in the professional development of mathematics teachers is considered. Appendices contain a survey on student beliefs about problem solving, a "solo" problem-solving test, interview questions, a year-end class survey, and tables illustrating individual student scores by class period. (MKR)

MATHEMATICS TEACHER DEVELOPMENT: LESSONS LEARNED FROM TWO COLLABORATIVE ACTION RESEARCH PARTNERSHIPS

Anne M. Raymond
Department of Elementary Education
Indiana State University
Terre Haute, Indiana 47809

eeraymon@befac.indstate.edu
(812) 237-2859

A Paper Presented at the 1995 Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Columbus, Ohio.

MATHEMATICS TEACHER DEVELOPMENT: LESSONS LEARNED FROM TWO COLLABORATIVE ACTION RESEARCH PARTNERSHIPS

Anne M. Raymond
Indiana State University

Action research is becoming a recognized field of educational research (Calhoun & Glickman, 1993; Cardelle-Elawar, 1993; Hubbard & Power, 1993; Miller & Pine, 1990). Although action research is still in the process of being "defined," leaders in the field offer their characterizations. For example, Miller and Pine (1990) define action research as "an ongoing process of systematic study in which teachers examine their own teaching and students' learning through descriptive reporting, purposeful conversation, collegial sharing, and critical reflection for the purpose of improving classroom practice (p. 57)." Clift, Veal, Johnson, and Holland (1988) suggest that collaborative action research between university and school faculty, is characterized by its focus on practical problems of individual teachers or schools and its emphasis on professional development and support for collaboration between teachers and university staff.

There are a number of beneficial outcomes associated with action research. According to Miller and Pine (1990), "Teachers can contribute to educational improvement by conducting classroom research concerning teaching and learning processes. This "action research" role for teachers can enhance the professional status of teaching and generate theory and knowledge" (p. 57). Further, collaborative action research partnerships create rich opportunities for the professional development of teachers and classroom reform (Rafferty, 1995).

One of the primary goals of collaborative teacher research is to bridge the gap and strengthen the relationship between universities and schools (Calhoun & Glickman, 1993; Cardelle-Elawar, 1993; Miller & Pine, 1990). Collaborative research, between university researchers and classroom teachers, presents opportunities for a more "action-oriented" approach to teacher enhancement (Clift, Veal, Johnson, & Holland, 1988). As teachers are encouraged to reflect upon and systematically examine aspects of their classrooms, they are likely to make changes based on their observations that lead to improved teaching and learning in their classrooms. In addition, theorists claim (Cardelle-Elawar, 1993) and studies show (e.g. Raymond & Hamersley, 1995) that teacher-inspired action research has the potential to result in immediate classroom reform because the results are more context specific and meaningful to the teacher.

Collaborative research projects in the classroom also leave a different impression on classroom teachers than do solely university-researcher investigations. This is primarily because with collaboration there is the sense of ownership in the investigation and a feeling on the part of the teachers that they have been "worked with" as opposed to "worked on" (Lieberman, 1986).

ACTION RESEARCH IN THE MATHEMATICS CLASSROOM

In the past year I have had the opportunity to participate in two collaborative action research projects with two middle school mathematics teachers. The first project was one in which a seventh-grade mathematics teacher wanted to change his mathematics teaching in an effort to more effectively address the National Council of Teachers of Mathematics' [NCTM's] (1989) call to infuse problem solving into the mathematics classroom. In doing so, he hoped to improve his students' attitudes toward and abilities in mathematical problem solving. The second collaborative project stemmed from an eighth-grade teacher's desire to investigate whether or not her efforts in teaching algebra through the use of "Hands-On" manipulative program were worthwhile. Specifically, she wanted to compare students' attitudes and academic achievement when working with the "Hands-On" manipulatives.

Both projects were teacher-driven and yielded a number of interesting results. Herein I (a) briefly describe the nature of the two studies, (b) talk about the process of engaging in collaborative action research, (c) discuss the similarities and differences between my roles in the two studies, and (d) offer my thoughts on the role of action research in the professional development of mathematics teachers.

A DESCRIPTION OF THE TWO STUDIES

The Collaborative Study With Brad

In this section I briefly explain the goals of the study and our research approach. I then highlight one of the many findings from the research in order to provide the reader with a "sense" of the study. For more complete findings from the entire collaborative study, see Raymond and Hamersley (1995).

Brad's collaborative action research study revolved around his desire to incorporate more problem solving into his seventh-grade mathematics curriculum. After having a number of conversations about what we each hoped to achieve from engaging in a collaborative study, we established three goals (a) to improve the seventh-grade students abilities in, knowledge of, attitudes toward, and beliefs about mathematical problem solving (b) to examine changes in Brad's mathematics teaching as we implemented the problem-solving curriculum, and (c) to learn more about the nature of collaborative action research in a mathematics classroom.

Both Brad and I believed that the primary reason for engaging in the project was to help the seventh-grade mathematics students become more knowledgeable about and confident in problem solving as well as become better problem solvers. However, Brad also expressed a personal goal of wanting to improve his own ability to teach mathematical problem solving in the spirit of the NCTM (1989) *Standards* and I was interested in examining issues associated with collaboration between university and school mathematics teachers and teacher educators. Thus, the project's goals include both individual and joint areas of interest.

Methodology

Implementing the Problem-Solving Curriculum. The study itself, which included collaborative planning, teaching, and documentation, began in September 1994 and continued through the May of 1995. The collaborative pair decided to approach the teaching of problem solving by introducing ten problem-solving strategies, one per week, for the first ten weeks of the study. We believed that it was important to encourage the students to use a specific strategy to solve given problems so that they would begin to get a feeling for what types of problems might naturally "call for" a particular strategy. We told students that although the problems we were doing in class could be solved by a number of strategies, we wanted them to first try solving it using the "strategy of the week" so that they would become familiar with the strategy. We further explained that we would be interested in talking about other strategies that they might use and that after we had introduced the ten strategies to them, we would leave it up to them to choose the strategy or combination of strategies they wanted to use.

Brad selected the ten strategies that he wanted to introduce at the beginning of the year. He chose *guess & check*, *draw a picture*, *make a table*, *make an organized list*, *look for a pattern*, *work backwards*, *use logical reasoning*, *make a model/act it out*, *make it simpler/look at a smaller case*, and *create a Venn diagram*. We proceeded to introduce them to students in the order listed above. I co-taught in Brad's classroom on Thursday mornings during Brad's first two mathematics classes and Brad taught the same lesson to the other participating classes later in the day. Brad then taught a related lesson the following Tuesday, which emphasized the same problem-solving strategy introduced on the previous Thursday.

Participants and Data Collection. The participants included approximately 125 seventh-grade mathematics students at a large middle school in Indiana. The students were mostly Caucasian Americans and came from socioeconomic backgrounds that ranged from lower middle class to upper middle class.

Data were collected through a variety of sources. To examine changes in students' attitudes, beliefs, and knowledge about problem solving, we implemented pre-problem solving and post-problem solving surveys that included multiple choice questions and short answer questions. The first survey (see Appendix A) was given to the students at the beginning of the school year, before we began our problem solving lessons. The students were later given a slightly revised version of the survey in February of the school year. The questions probed students about a variety of issues including their confidence in problem solving, their feelings about problem solving, their definitions of problem solving, problem-solving strategies they know, and how they solve mathematical problems. Data on students' attitudes and knowledge were also collected via teacher-researcher observations (which were subsequently documented in researcher journals) and student reflections.

Changes in students' abilities were documented primarily through student work and documented classroom observations. Additional data on students' abilities in problem solving was collected via a "problem solving test" that was implemented at the end of the school year over a period of five days. This "collaborative team designed" test (see Appendix B) consisted of a variety of nonroutine problems that could be solved using the strategies emphasized throughout the study.

Data regarding changes in Brad's teaching were gathered through self-observation and self-reflection as well as through documented observations made by me. Information about the nature of collaborative inquiry was also collected via observation and reflection on the part of both teacher-researchers. Throughout the study, both researchers maintained reflective journals. Both reflected after each Thursday session. In addition, Brad wrote a journal entry after each Tuesday follow-up lesson. The two researchers met periodically after school to discuss observations and share reflections. Synopses of these discussions were added to the reflective journals.

Analysis. Data analysis included the compilation of comparative survey statistics, the reading and comparing of short answer responses on surveys, the comparison of early student work to later work, and team sharing of observations and reflections. Once the second survey had been implemented, we calculated percent responses to the survey questions in order to locate any changes in students' attitudes, beliefs, and knowledge about problem solving. When there was an observed change, we discussed that change together, sharing any observations that might support that finding.

One Finding: Changes in Students' Attitudes and Beliefs

Analysis of data on students' attitudes and beliefs about problem solving resulted in several interesting findings. For example, upon comparing students' responses to the multiple choice questions on the first survey to their responses on the second survey, significant changes were noticed in eight areas (see Table 1).

Table 1
Changes in Attitudes and Beliefs from Survey 1 to Survey 2

	Percent that Agreed or Strongly Agreed	
	Survey 1	Survey 2
I Like Problem Solving	43	74
I Can Do Problem Solving	63	91
I Am Not Confident in Problem Solving	56	25
Problem Solving is Easy	27	56
Problem Solving is Important to Learn	61	98
Some People Can't Do Mathematics	58	43
It is Important to Be Able to Do Math Quickly	18	38
I Know A Lot About Problem Solving	21	54

The findings are very encouraging in that they indicate that the percentage of students who expressed that they like problem solving and can do problem solving increased over the first six months of the project. Other positive results evident from Table 1 are that fewer students expressed that they lacked confidence in their problem solving abilities and that they believe some people cannot do mathematics. Also, more students indicated that they know a lot about problem solving and that problem solving is important to learn.

The one of the disturbing results from this portion of the survey was that the percentage of students who believed that it is important to solve mathematics quickly increased over the six-month period. After acknowledging this result, Brad and I reflected upon our teaching styles in an effort to determine if our actions might have encouraged more students to arrive at this conclusion. We concluded that we may have contributed to this belief by presenting too many problems in each lesson and conducting whole-class discussions after a certain period of time had been given to work on the problems. We feel that perhaps we sent the message that the students should have been able to complete the problems in the time frame we allotted. As a result of this finding, we became more sensitive to the issue of time by including fewer problems in the lessons and by eliminating the "whole class discussion" of problems between problems. Rather, we fostered "group pace" and provided a less structured opportunity for whole-class wrap up at the end of the class period. We also began to defer discussion of some problems to a later time.

The Collaborative Study With Marylin

The collaborative action research project with Marylin stemmed from her desire to examine the outcomes of classroom reform she had initiated in her classroom. Specifically, Marylin used a "Hands-On"[1] approach to teaching algebra to eighth-graders and she wanted to know if her efforts were "worthwhile." In our study, we defined worthwhile, and investigated the "worthiness of her efforts," by determining whether the following have took place as a result of the implementation of a mathematics manipulative program in her classroom:

- increased self-esteem
- increased confidence
- increased interest/motivation
- increased sense of independence
- increased ability to solve algebraic equations
- increased durability/ability to succeed in traditional high school algebra class.

As the list above suggests, our interests were in studying both academic outcomes as well as changes in outcomes in the affective domain. Consequently, the focus of the study was to investigate: (1) Does the use of these mathematics manipulatives in an algebra class increase students' self-esteem, confidence, sense of independence, and interest in solving algebraic problems? and (2) Does the use of these mathematics manipulatives in an algebra class increase students' ability to correctly solve algebraic equations and increase the level of retention of algebraic skills beyond the eighth-grade experience?

[1] The program implemented was entitled "Hands-On Equations" created by Dr. Henry Borenson.

Methodology

Study Format. This study has two phases. The first phase of this study took place during the 1994-95 school year. For the first nine weeks of the school year, Marylin taught in a non-manipulative style, teaching solely from the adopted textbook. Following this nine-week period, she implemented the 26-lesson program, "Hands-On Equations." In short, the materials in this program introduce students to a manipulative approach to solving algebraic equations, and guide them through an intermediate pictorial approach, culminating in engaging students in activities that relate the manipulative to the more formal "high school" algebra. Marylin completed this program prior to December 15, 1994. At the beginning of the post-Christmas term, she went back to an "all book" approach to teaching algebra, which continued through the end of the school year.

The second phase of the study is currently underway and takes place over the course of the 1995-96 school year, during which time we continue our investigation of these same students who have moved on to high school. We are studying their high school experience in order to ascertain the "durability" of the results of the manipulative experiences in Phase One. We anticipate that we will survey as many graduates from Marylin's class as possible and also conduct one-on-one interviews with a minimum of eight students.

Participants and Data Collection. The subjects of our study include four classes (periods) of eighth-grade students, totaling approximately 120 students at a lower class, inner city middle school in Indiana. Data collection methods include surveys, student and teacher reflection, student work samples, individual interviews, and group interviews.

Data on student's self esteem, confidence, feelings of independence, and interest level were gathered at the end of the school year through a beliefs/attitude/knowledge survey (see Appendix C), students' written reflections, teacher observations and teacher reflections. In addition, two "class periods" were interviewed as a whole group by me (see Appendix D for guiding questions used during the interviews). These interviews were audiotaped and later transcribed. They focused on students' attitudes toward learning algebra by working with mathematics manipulatives as opposed to working solely with a textbook.

Data about students' ability to solve algebraic equations were being gathered through student work samples and student quiz tests scores during both the "manipulative phase" and the "book" phase. Some students were also videotaped while demonstrating algebraic solutions during class time. These videotapes serve as another source of data on students' abilities in algebra. In addition, all eighth-grade students at the middle school took a mandatory standardized algebra test at the end of the school year. Finally, students' surveys, reflections, and work were stored in student folders in the room. Once a week, students were asked to look through their folders and reflect on their learning, specifically on any changes they have noticed.

Data Analysis. Marylin and I are currently analyzing the data together. Thus far, audiotapes from the whole-class interviews have been transcribed and data from the survey have been complied and initially sorted by question asked. Data will be more thoroughly and systematically reviewed and sorted into thematic categories. Surveys will be analyzed qualitatively and quantitatively, identifying simple statistics such as means and modes. Overall quiz and test scores earned during the "manipulative" stage of the algebra course have been compared to quiz and test scores earned during the "textbook" stage of the course. However, we intend to do a more thorough comparison of scores by breaking down textbook scores into "before" the manipulatives and "after" the manipulatives.

An Initial Finding from Marylin's Study

As we began our data analysis, we first compared overall class grade averages from the textbook phase to those earned during the manipulative phase. Table 2 shows these initial results. Overall class averages were higher during the manipulative phase than the textbook page. (Appendix E shows individual student results by class. For the most part, individual students scored better during the manipulative phase. Some of the differences were quite significant. There were a few students, however, that did not have higher scores during the manipulative phase.)

Table 2
A comparison of class averages during periods of textbook instruction and manipulative instruction.

	Class Average	
Class Period	Textbook	Manipulatives
1st	65%	82.38%
2nd	70.47 %	81.28%
3rd	75.07%	85.29%
6th	81.4%	87.82%
7th	72.16%	82.1%

As mentioned earlier, we intend to further explore how student scores breakdown as we look specifically at grades earned during textbook work both prior to and following manipulative work. We are not certain what these results will allow us to "claim." However, we believe that further exploring this data, and other data collected, will better inform Marylin's practice, which is, after, a primary goal of action research.

ENGAGING IN COLLABORATIVE ACTION RESEARCH PROJECTS

Establishing research projects to be designed and implemented jointly by classroom teachers and university faculty is not a simple task (Raymond, 1994). In the cases of Brad and Marylin, the partnerships were formed differently. However, in both cases, the teachers involved were teachers who were *ready* for change and who were *attempting to initiate change* in their classrooms.

My partnership with Brad emerged during a summer graduate course I was teaching in which Brad was a student. A focus of the course was on teaching mathematics via problem solving. Prior to the course, Brad had begun to make efforts to incorporate problem solving into his classroom teaching. However, as the course progressed, Brad realized that there was much more that he could be doing, and he became interested in changing the way he approaches problem solving in his classroom.

Brad admitted having some trepidation about how he would go about making changes. I offered to assist him in making those changes by co-planning and co-teaching some problem-solving lessons. Brad was eager to engage in this collaboration. When I later asked Brad if he would be interested in documenting his efforts through collaborative action research, Brad was interested.

In Brad's case, I suggested the partnership. However, only after I sensed that Brad was a teacher ready to make changes did I approach him about systematically documenting his reform efforts.

Marylin, too, was teacher involved in change. An energetic mathematics teacher of 20 years, Marylin was suddenly placed in a new position. Her middle school had decided to implement an "algebra for all" program. Thus, all eighth-graders at her school were to be enrolled in algebra. Marylin found herself facing classes of eighth-graders ranging from special needs to gifted and did not believe that she would be able to reach all of the students through a traditional textbook approach to algebra. She happened upon the opportunity to attend a workshop on teaching algebra through the "Hands-On Equations" program and was impressed by what she saw.

As she began to teach the program during the tenth week of school, she started to worry about whether or not this was a good idea. It was at this point that she spoke about her concerns to one of my colleagues who spent time at the middle school with preservice teachers. My colleague suggested to Marylin that she contact me since she knew I was a person interested in mathematics education and collaborative research.

Marylin called me, introduced herself and her dilemma, and asked if I might be willing to talk with her about possible engaging in some collaborative research. I accepted and met with Marylin to discuss what she wanted to "find out."

In Marylin's case, it was she who initiated the study and the partnership. She sought me out because she did not know how to go about conducting a research project and needed my expertise in that area. Like Brad, she was a teacher who was already involved in making a change, but who was not completely confident in the change. Thus, this appears to be a common element between the two teachers. The process of the formation of the partnerships ultimately played a role in the determination of roles played by each of the collaborative partners. In short, the initial relationships formed between Brad and myself and Marylin and myself set the stage as the collaborative action research projects unfolded.

A COMPARISON OF ROLES PLAYED IN THE TWO STUDIES

Although the notion of valuing "teacher as researcher in the classroom" is growing among educational researchers (Cardelle-Elawar, 1993; Rafferty, 1995), probably the most difficult phase of conducting action research is encouraging teachers to believe in their abilities to be effective classroom researchers. As a result, a challenging aspect of conducting collaborative action research is developing a sense of the roles each of the partners is to play. It is certainly true that I played some of the same roles in both of the projects. However, there were also some definite differences in the ways that I interacted with Brad and Marylin during our collaborations.

With Brad, our roles evolved throughout the project. At the beginning we were both hesitant to step out of what we had assumed would be our natural roles. For example, I felt that my primary role would be to provide resources, guide the development of a framework for the research, and "teach" Brad about gathering, analyzing and reporting data. I felt strongly, at the beginning, that I should defer to Brad when it came to making decisions about what would take place in his classroom. Similarly, Brad was comfortable with allowing me to make suggestions about how the research and took charge of issues such as how problem solving would be implemented into his mathematics classroom and how much time he could realistically devote to problem solving.

At one point when we sat down specifically to discuss what we had learned about collaborative research, what we talked most about were the changes in the roles that we played throughout the project and the evolution of the collaborative partnership to that of a collegial friendship. The roles that we played went through a number of changes. Initially, I was the experienced researcher, the "expert" teacher of problem solving, and the resource provider. Brad was the seventh-grade mathematics expert, the classroom disciplinarian, and the classroom decision maker. When teaching, I typically, although it had not been specifically planned this way, started off the lessons while Brad began the wrap-up discussion of problem solutions.

As the weeks progressed, Brad was offering suggestions for ways to gather data. For example, it was Brad who initially suggested we ask students to write the first reflection on strategies. Anne began to take a more active role in classroom management during the lessons. In addition, the two began to naturally trade off the role of the lesson motivator and the discussion leader. Never did we explicitly discuss the roles we played. Rather, as we became more comfortable with each other and more sure of our approach to implementing problem solving in Brad's classroom, we "assumed roles" less and less. It no longer felt like we had distinct duties within the partnership. Instead, everything became a joint duty.

We contend that the initial feeling of playing distinct roles arose because each member of the collaborative team was a supposed "expert" in certain areas and yet at the same time neither person wanted to inhibit the other partner by making him/her feel his/her opinion or perspective was not equally valued in all phases of the collaboration. The mathematics classroom setting may more vividly present images of "experts" because mathematics is an area in which many people feel insecure. In our case, Brad expressed at times that he felt more comfortable with letting me conduct the question and answer time of the lesson because he felt I could see more mathematical connections and perhaps respond to students' solutions more effectively.

There may be expectations associated with "being good at mathematics" and "being a good mathematics teacher" that put additional pressures on collaborative partners who conduct action research in mathematics classrooms. These pressures may result in the partners automatically taking on specific roles in the beginning of a joint teaching-research venture.

In Marylin's case, I did not do any of the teaching. Marylin was in complete control of what was happening in the classroom. She was also very up front in expressing her belief that I was the researcher and she was the teacher. She constantly asked me questions like, "How should we gather data about that?" "Should I be writing this down in my reflective journal?" "Now, you'll show me how we can analyze this, right?" Oddly enough, I noticed that Marylin offered as many suggestions on how to gather and analyze data as I did. However, each time I countered her comment that I was the researcher by saying, "We're both the researchers," she insisted, "No, no, I'm just the teacher."

From my perspective, Marylin has done most of the work in our collaboration. Although we talked about what to collect, she has done the collecting. In addition, she has done a considerable amount of the reflection upon and analysis of the initial data. In a strong sense, I have felt more like a "coach" with Marylin than I did with Brad.

In both cases, when it came to writing about our findings for one purpose or another, I typically did the bulk of the writing. I would draft a paper and then have them react to and edit the piece. They both felt most comfortable with this arrangement. In terms of becoming familiar with literature related to their studies, I provided Brad with literature to consider. Marylin, on the other hand, would come across an article and give it to me say, "This is a good article to read. It makes me feel like what we're doing is on the right track."

The two cases present an interesting comparison. In both cases, the partners were eager to do anything I suggested. And in both cases the teachers made considerable suggestions themselves. Brad and I seemed to have "distinct" roles at the beginning, which ultimately disappeared. Marylin, while I have viewed her as more if an equal partner from the beginning in terms of actions and abilities, continues to view our roles as distinct. Role played and roles perceived certainly do differ in some cases.

The "Larger" Relationship and the Development of Roles

The development of roles in the two partnerships most likely was highly influenced by the larger relationships between myself and the two teachers. One influence may have been the timing of the two projects in that my project with Brad began before my project with Marylin. I may have felt more relaxed with the notion of collaboration when I met with Marylin because I had already experienced such a collaboration with Brad. This may have resulted in my having a different perception of the roles I believed I was to play and the roles I expected Marylin to play.

Another issue that may have influenced the initial development of roles is the means by which we met. Recall my original relationship with Brad was that of student and teacher. Although I try to create a very relaxed atmosphere with graduate students and insist that they call me Anne, while a student, Brad continued to call me Dr. Raymond. Once engaged in the study, Brad still referred to me as Dr. Raymond. Eventually Brad arrived to the point where he laughingly referred to me as "Raymond." Brad gradually came to a point where he called me Anne, although at that point I had started calling him "Hamersley." It may seem insignificant to talk about how the partners addressed each other. However, the "titles" we give to one another often perpetuate our differences rather than emphasizing what we have in common.

Marylin was introduced to me as Anne, and has never called me Dr. Raymond, except in reference to me to her students. This may have made me perceive our partnership as more equal from the beginning.

Other influences on how roles developed might have been gender and personality differences. Marylin and I seemed to form an immediate bond as we talked about our philosophies of teaching and mathematics. We found considerable commonalties among not only our philosophies but in our personal backgrounds. Brad and I also discovered that we had similar beliefs about teaching and mathematics. And even though we discovered we agreed on many issues, there were some clear differences in our lifestyles and opinions on gender-related issues.

Although this did not keep us from becoming good friends, there was a recognizable difference between us which may have influenced the evolution of the roles that we played.

THE ROLE OF ACTION RESEARCH IN THE PROFESSIONAL DEVELOPMENT OF MATHEMATICS TEACHERS

There were a number of ways that these action research projects provided numerous opportunities for professional development for Brad and Marylin. Both certainly became more reflective practitioners as they engaged in their collaborative action research projects. In addition, Brad improved his ability to teach mathematical problem solving to seventh-grade students, changed his classroom questioning techniques, and altered the environment of his classroom. Marylin reaffirmed her initial belief in teaching mathematics through "Hands-On" manipulatives, believes more strongly in having her students take control of their learning, and has found that her students feel more confident in their abilities to solve algebraic equations.

Outside of the classroom, Brad and Marylin have engaged in further professional growth. Brad and I have made numerous presentations on our joint project. Together we presented at the National Council of Teachers of Mathematics meeting and the Indiana Middle Level Education Association meeting. We have also jointly presented at a local school board meeting and as invited guests in a graduate course at the university. Brad has also come into my mathematics methods classrooms and talked about becoming a more reflective mathematics teacher through systematic action research. In addition, Brad gained the experience of writing a proposal for and receiving a grant to fund part of his research efforts through the graduate office at the university.

Marylin has also engaged in professional growth experiences. Together, she and I have made a presentation at the Indiana Council of Teachers of Mathematics Meeting and at a Collaborative Inquiry Conference hosted by the university. She, too, has been a guest speaker in my classroom and we have both been invited speakers in a graduate class at a neighboring university. She and I jointly composed a proposal and received a grant from money allocated from Lilly Endowment to fund our research efforts. In addition, we have had a paper accepted for publication in an upcoming Collaborative Inquiry Monograph.

All of these professional development experiences have increased Brad's and Marylin's confidence and has brought them recognition by their administrators. The experiences have also stimulated in them a desire to continue to pursue inquiry as a means of professional development. Although these professional outcomes for Brad and Marylin have been positive, the field of action research still poses considerable challenges.

Challenges of Action Research

Noffke (1994) suggests that there are four contemporary challenges for action research. First, to many, the only goal of action research has been seen as lying within the area of personal and/or professional development. As a result, action research is often valued "less for its role in the production of knowledge about curriculum, pedagogy, and the social contexts of schools, and more for its ability to help teachers grow in their self-awareness or in terms of their professional skills and dispositions" (p. 15). Although both Brad and Marylin experienced tremendous benefits in the area of professional development, let us not forget that they investigated serious questions of mathematics curriculum and pedagogy. They made "discoveries" about these issues. Thus, one way to move action research beyond being seen merely as a means of professional development is for teachers to more openly report their research findings as a contribution of knowledge to their particular field of educational research.

Second, is the question of whether action research is "real research" merely made small enough for practitioners, or whether it is "a new form of research whose methods, methodology, and epistemology are only now being clarified?" (p. 16). I am not sure that the cases of Brad and Marylin alone can answer that question. We certainly approached our studies as if they were "real research," but the overall results of the study, including negotiation of roles, classroom reform, and the inevitable dimension of professional development, encompass so much more than the findings from the original research questions that I tend to believe that action research is a new form of research in and of itself.

Third, are the politics of knowledge production and the establishment of "relationships" in the breaking down of the barriers of isolation within teaching and across schools and universities.

Clearly, with Brad, Marylin, and myself barriers have begun to break down. This was most evident through the evolution of my relationship with Brad, moving from the graduate student-university professor relationship to the ultimate collegial partnership.

Finally, Noffke (1994) suggests that action research plays a role in social transformation in its concern for systemic change. In the case of Brad, several of the other mathematics teachers at the middle school wanted to know who I was and why I was teaching with him. They were interested in the problem-solving situations that Brad's students were engaged in and wanted to learn more about teaching problem solving. This interest led to the principal asking Brad to do a presentation to the mathematics faculty in which he shared the materials he and I had used and talked about how we incorporated problem solving into his classroom. This, to me, suggests that action research can lead to broader systemic change, even when it begins with a one-on-one partnership.

In Closing

The ultimate reward of action research is that one is often able to witness simultaneous research, reflection, and reform. Participation in two action research projects in mathematics classrooms has offered me two very interesting research opportunities. Not only have I learned what kinds of mathematics-related issues concern teachers, but I have observed two mathematics teachers working for change and finding success. Collaborative research affords a university researcher the opportunity to learn of and investigate a question that someone else finds interesting. The process challenges one's perception of what are the really important research questions and encourages the university researcher to rethink her own teaching and goals of inquiry (Fullan, 1993).

References

Calhoun, E.F., & Glickman, C. D. (April, 1993). *Issues and dilemmas of action research in the league of professional schools.* A paper presented at the Annual Meeting of the American Educational Research Association, Atlanta, GA.

Cardelle-Elawar, M. (1993). The teacher as research in the classroom. *Action in Teacher Education, 15*(1), 49-57.

Clift, R., Veal, M. L., Johnson, M. & Holland, P. (19?8). Restructuring teacher education through collaborative action research. *Journal ofTeacher Education, 41*(2), 52-62.

Fullan, M. (1993). *Change forces: Probing the depths of education reform.* New York: The Falmer Press.

Hubbard, R. S, & Power, B. M. (1993). *The art of classroom inquiry: A handbook for teacher-researchers*, Portsmouth, NH: Heinemann Educational Books, Inc.

Lieberman, A. (1986). Collaborative research: Working with, not working on. *Educational Leadership, 43* (5), 28-32.

Miller, D. M. & Pine, G. J. (1990). Advancing professional inquiry for educational improvement through action research. *Journal of Staff Development*, 2(3), 56-61.

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: NCTM.

Noffke, S. (1994). Action research: Towards the next generation. *Educational Action Research*, 2(1), 9-21.

Rafferty, C. D. (February, 1995). Impact and challenges of multi-site collaborative inquiry initiatives. *Paper presented at the Annual Meeting of the American Association of Colleges for Teacher Education*, Washington, DC.

Raymond, A. M. (1994). Collaborative action research in mathematics education: A tale of two teacher-researchers. In D. Kirschner's (Ed.) *Proceedings of Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*, Baton Rouge, LA.

Raymond, A. M. & Hamersley, B. (1995). Collaborative action research in a seventh-grade mathematics classroom. *Paper presented at the Research Presession of the Annual Meeting of the National Council of Teachers of Mathematics.* Boston, MA.

Appendix A

Students' Beliefs About Problem Solving

For each of the following, circle the response that best describes your feelings about mathematical problem solving. SA means you strongly agree, A means you agree, U means you are uncertain, D means you disagree, and SD means you strongly disagree.

	(circle one)				
1. I like mathematical problem solving	SA	A	U	D	SD
2. I can do mathematical problem solving	SA	A	U	D	SD
3. We do a lot of problem solving at school	SA	A	U	D	SD
4. I am not very confident about problem solving	SA	A	U	D	SD
5. There is more than one right way to solve story problems	SA	A	U	D	SD
6. It is best to work by yourself on problem solving	SA	A	U	D	SD
7. Boys are better at problem solving than girls are	SA	A	U	D	SD
8. Problem solving is easy for me	SA	A	U	D	SD
9. In problem solving, getting the right answer is most important	SA	A	U	D	SD
10. Problem solving is important to learn	SA	A	U	D	SD
11. Working with a partner is helpful in problem solving	SA	A	U	D	SD
12. Some people just can't do problem solving	SA	A	U	D	SD
13. I know a lot about problem solving	SA	A	U	D	SD
14. It is important to be able to solve problems quickly	SA	A	U	D	SD
15. There is one right answer to story problems	SA	A	U	D	SD
16. I can tell when I have solved a problem correctly	SA	A	U	D	SD
17. Problem solving is difficult for most people	SA	A	U	D	SD
18. I would like to be a better problem solver	SA	A	U	D	SD

Select one of your answers above and explain why you feel the way you do:

Survey, page 2

Name: ______________________________ Date: ___________

Provide a short answer to each of the following questions.

1. What do you think "problem solving" in math class is?

2. Problem solving in math makes me feel ...

3. When I'm given a story problem in math class, the first thing I do to solve the problem is ...

4. Some problem solving strategies I know are ...

5. How do you know when you've solved a math story problem correctly?

6. Why do you think it is important to learn about problem solving in mathematics?

Appendix B

"Solo" Problem Solving Test Given to Brad's Students

Solve the following problems using the problem-solving strategy, or strategies, of your choice. For each problem, write a paragraph describing how you solved the problem.

1. How many different ways are there that you can give a person 30 cents in change?

2. On the way to school, Joyce invited a friend to come over after school to watch a video. At the end of first period class they each invited another person. At the end of each class period everyone who knew about the video invited another person. If there were 7 class periods in the day, how many people total were invited to Joyce's house after school?

3. While on a canoe trip, John, Dave and Pam took turns paddling. Pam paddled 6 kilometers less than Dave. Dave paddled twice as far as John who paddled for 14 kilometers. How long was the total trip?

4. Jeri went shopping for the day. The shoe store is 6 minutes directly south of the clothing store, and the department store is a 6 minute walk directly south from the restaurant. There is a sports shop west of the clothing store, and the department store is a 10 minute walk east from the shoe store. Jeri left the restaurant at 1:00 PM, spent 35 minutes shopping for clothes and then went straight to the sports shop. She arrived at the sports shop at 1:53 PM. How long did it take her to walk from the clothing store to the sports shop?

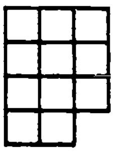
5. Each different letter stands for a different number in the problem below.

$$\begin{array}{r} \mathbf{A\,D\,D} \\ \underline{+\,\mathbf{D\,O}} \\ \mathbf{D\,A\,D} \end{array}$$

Find the number each letter represents to make this a correct addition problem.

6. Suppose you have a 3 gallon bucket and an 8 gallon bucket and you need to measure out 4 gallons of waer. But, neither of the buckets have any markings on the side. How can you do this?

7. How many squares are in this drawing?



8. Mary, Tom and Brett divided a bag of marbles. Mary would get 5 for every 3 Tom received and every 4 Brett received. If Tom ended up with 27 marbles, how many did Mary and Brett receive altogether?

9. In numbering the pages of a book, I used 57 digits. What was the last page numbered? (Page 1 is numbered 1, using one digit).

10. Pencils cost 15 cents and erasers 10 cents. How many different ways can you purchase pencils and erasers and spend 90 cents?

Appendix C

Interview Questions for Marylin's Class

1. Do you think you're learning more algebra when you're using the manipulatives or using the book? Why?

2. Can you specifically give examples that if/when you've made use of your experience/knowledge of manipulative work when working textbook problems?

3. Do you really think manipulative work will help you later when you're doing algebra in high school or was it just fun and a way to get good grades?

4. Would you have rather just stayed with the textbook all semester rather than take time out to work with manipulatives?

5. How comfortable were you when you took tests/quizzes with manipulatives? Why?

6. Would you recommend using manipulatives to other 8th grade students? Why/why not?

7. What was the thing you liked least about using manipulatives? What did you like the most?

Appendix D

Year-End Survey Given to Marylin's Students

Name: ______________________ Period: _________ Date: _____________

1. How did you feel last August when you learned that all eighth graders were going to be in algebra?

2. How did you feel about algebra by Christmas break when you had finished the manipulative lessons?

3. How do you now feel about algebra at the end of the school year?

4. How would you rate your knowledge of algebra?
(Check one) Low ____ Medium ____ High ____
Explain your rating:

5. How would you rate your confidence in doing algebra?
(Check one) Low ____ Medium ____ High ____
Explain your rating:

6. What are your strengths in algebra?

7. What are your fears about taking algebra in high school?

8. Using Dr. Borenson's "Hands-On" Equations method, solve the following equation with the "pictorial" method and explain how you did it:

$$2x + x - x + 1 = x + 9$$

Explain:

9. Multiply the following and explain how you did it:

$$(7x + 5y)(x - 4y)$$

Explain:

10. How has the study of algebra affected your basic math skills? (skills that were tested on I-STEP)

11. How did writing in your journals affect your learning of mathematics?

12. Describe the atmosphere in Mrs. Leinenbach's class.

13. Were you comfortable asking and answering questions in class?
(Check one) Yes ____ No ____ Sometimes _____
Explain your answer:

Survey, page 2

14. Did you like working on mathematics with partners and groups?
(Check one) Yes ____ No ____ Sometimes _____
Explain your answer:

15. How would you rate your self-discipline in mathematics - that is, the level at which you try all problems and don't give up, even when some problems are hard?
(Check one) Low ____ Medium ____ High ____
Explain your rating:

16. Which did you like better:
(Check one) Using the textbook ____Working with manipulatives ____
Explain:

17. When did you learn more algebra:
(Check one) When using the textbook ____ When working with manipulatives____
Explain:

18. What would you change about the algebra program?

Appendix E

Tables Illustrating Individual Student Scores by Class Period

Table 3

Comparison of individual student grades during textbook and manipulative instruction: 1st Period

	Individual Student Grades	
Student Name	Textbook	Manipulatives
EVER	62 %	91.3 %
JEN	76.3 %	81.7 %
RANA	76.8%	89.2 %
ACE	73.4 %	88.9 %
PETEY	74 %	92.6 %
DUD	61.5 %	79.5 %
BLADE	54.9 %	92.8 %
RUDE	62.1 %	71.6 %
CF	48.5 %	65.3 %
AMANDA	49.5 %	76.4 %
BRANDI	53.5 %	58 %
BETTY	52.7 %	65.7 %
TAZ 2	71 %	86.9 %
TAZ	59.6 %	84.5 %
PEACHES	70 %	78.8 %
BROTHER MAN	77.3 %	96.2 %
JASON	62.1 %	79.3 %
KENNY	60.2 %	87.5 %
BEAN PIE	51.8 %	60.6 %
$$$	45.5 %	73.6 %
COWBOY	90.6 %	99 %
MATT	62.6 %	85.3 %
ERIN	77.3 %	94.5 %
HOOP DOG	83.7 %	91.3 %
RHONDA	85.1 %	97.1 %
LM	61.2 %	74.8 %

Table 4

Comparison of individual student grades during textbook and manipulative instruction: 2nd Period

	Individual Student Grades	
Student Name	Textbook	Manipulatives
RED	80.8 %	90.3 %
BONKERS	79.5 %	90.3 %
TAMEKAH	66.4 %	77.9 %
CRAZY	77.3 %	89.6 %
ROGGER RABBIT	79.3 %	91.7 %
GOOFY	75.2 %	74.5 %
WHINEY	86.3 %	92.7 %
MELISSA	85.6 %	91.1 %
TWEETY	59.5 %	27.8 %
8-BALL	72 %	88.4 %
JD	30.5 %	51.5 %
SNOOPY	68.3 %	87.1 %
FREE WILLY	66.9 %	61.3 %
D.J.	63.7 %	77.5 %
S.M.S.	68.3 %	71.9 %
RICO	85.5 %	94.6 %
MARCI	84.3 %	89.4 %
NIKKI	89.6 %	97.5 %
MY	75.2 %	64.6 %
J.M.	85.2 %	95.6 %
NEICEY	81.8 %	85.2 %
6	46.2 %	61 %
AALIYAH	80.3 %	77.2 %
BLADE	65.9 %	84.8 %
ORIGINAL	38.6 %	100 %

Table 5

Comparison of individual student grades during textbook and manipulative instruction: 3rd Period

Student Name	Individual Student Grades	
	Textbook	Manipulatives
ACE	91.5 %	100 %
MARY POPPINS	75.9 %	83 %
LARRY	91.5 %	100 %
SHAWN	83.9 %	94.6 %
LADY	82.5 %	85.5 %
NINET	21.7 %	42.2 %
PEACE	60.6 %	71.1 %
JERRY	78.5 %	92.5 %
MIKE	76.7 %	89.4 %
TRACY	88.7 %	92.3 %
KELLYN	90 %	92.9 %
TEVIN	75.6 %	78.7 %
A.D.	59 %	57.6 %
JO	29.3 %	NO GRADE
MONTEL WILLIAMS	85.3 %	72.2 %
P.J.	85.6 %	80 %
AMANDA	94.1 %	100 %
TWEETY	90.9 %	96.7 %
BARAKA	83.9 %	99.9 %
HEATHER	81.1 %	97.9 %
84	93.3 %	99.5 %
C	57.4 %	65.9 %
ROSE	92.7 %	96.1 %
CHRIS	45.2 %	83.5 %
SPEEDY GONZALES	62.2 %	75.5 %

Table 6

Comparison of individual student grades during textbook and manipulative instruction: 6th Period

	Individual Student Grades	
Student Name	Textbook	Manipulatives
AGBA	90.6 %	92.1 %
LER	85.1 %	95.1 %
SPEEDY	78.8 %	92.2 %
ED	68.9 %	92.3 %
I-65	81.8 %	83.3 %
WILE E. COYOTE	90.4 %	96.6 %
JERRY RICE	90 %	96.2 %
STEPHEN	81.5 %	79.4 %
GARY	86.4 %	84.3 %
MATTIE	71.4 %	79 %
G. Q. SMOOVV	88.4 %	87.5 %
EN	80.4 %	NO GRADE
RICHARD	85.4 %	85.5 %
THE LION KING	88.3 %	100 %
FOLD IN HALF	83.1 %	81 %
LR	69.3 %	87.3 %
HALF PINT	65.9 %	64 %
MYRON	86.1 %	91.3 %
THIS IS DA SHAU	69.7 %	86.2 %
NATE	80.6 %	89.5 %
BUNNY	87.3 %	93.8 %

Table 7

Comparison of individual student grades during textbook and manipulative instruction: 7th Period

Student Name	Individual Student Grades: Textbook	Individual Student Grades: Manipulatives
B.J.	72.2 %	73.2 %
QB	90.6 %	97.1 %
SISSY	93.6 %	98.1 %
TAZ	90.3 %	90.5 %
MIKE	9 %	0 %
DRS	62.3 %	78.7 %
MIGHTY	76.9 %	94 %
JAKCJ	90.8 %	96.5 %
JMJ	92.2 %	97.4 %
CL	67.1 %	80 %
SWEET SABLE	70.1 %	78.4 %
KRAZY	45 %	46.2 %
M&M	68.1 %	73.1 %
DOC	71.6 %	90.7 %
DADDY	71.1 %	93 %
AC/DC	71.2 %	92.4 %
ROAD RUNNER	69.8 %	89.9 %
COYOTE	90.6 %	97.7 %
SMARTS	86.4 %	100 %
ROSE	60.7 %	81.6 %
STRAWBERRY	61.7 %	52.2 %
MASTER	82 %	98.4 %
ROADKILL	66.1 %	89.4 %